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CIRCULAR No. 511 JANUARY 1939
UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

CONTROL OF BLACK ROT OF PINEAPPLES IN TRANSIT

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INTRODUCTION

Black rot of pineapples, caused by the fungus *Thielaviopsis paradoxa* (DeSeyn.) Hoehn., results in more loss in Puerto Rican pineapples during transit to New York than all other decays combined. Losses of 3 to 5 percent of fruit because of this decay are regularly expected by the dealers, but in shipments harvested immediately following or during prolonged rainy periods the losses often amount to 25 percent.

The decay is characterized by a water-soaked appearance and by a slight browning of affected tissues (fig. 1, *A*). It early becomes very soft and almost liquid, so that in late stages the flesh is so completely disintegrated that it yields to the slightest pressure. On exposed surfaces, decayed tissues become covered with a black crust composed of macrospores of the fungus. These also form in the decayed tissue near the core of the fruit, turning it black. The decay progresses rapidly and at room temperature will rot the entire fruit in 3 or 4 days.

The causal organism lives and sporulates freely on dead plant parts in the field, hence abundant inoculum is usually present at harvest-time. The organism usually gains entrance through the cut stem at the base of the fruit. Estimations made during commercial repacking in New York City, over a period of several years, indicate that from 70 to 80 percent of the black rot in Puerto Rican pineapples starts at the stem end. Most of the remaining 20 to 30 percent originates

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[1] The writers wish to express their appreciation to the following pineapple growers in Puerto Rico who furnished fruit without charge for these experiments: Porto Rico Consolidated Fruit Co., Enrique Landron, Isabela Grove Co., Morovis Plantation, Palo Blanco Fruit Co., Palo Seco Fruit Co., and the Hills Bros. Co. Acknowledgment is also made to the New York & Porto Rico Steamship Co. and the Atlantic & Caribbean Steam Navigation Co. for their cooperation in the transportation of experimental shipments from Puerto Rico to New York.

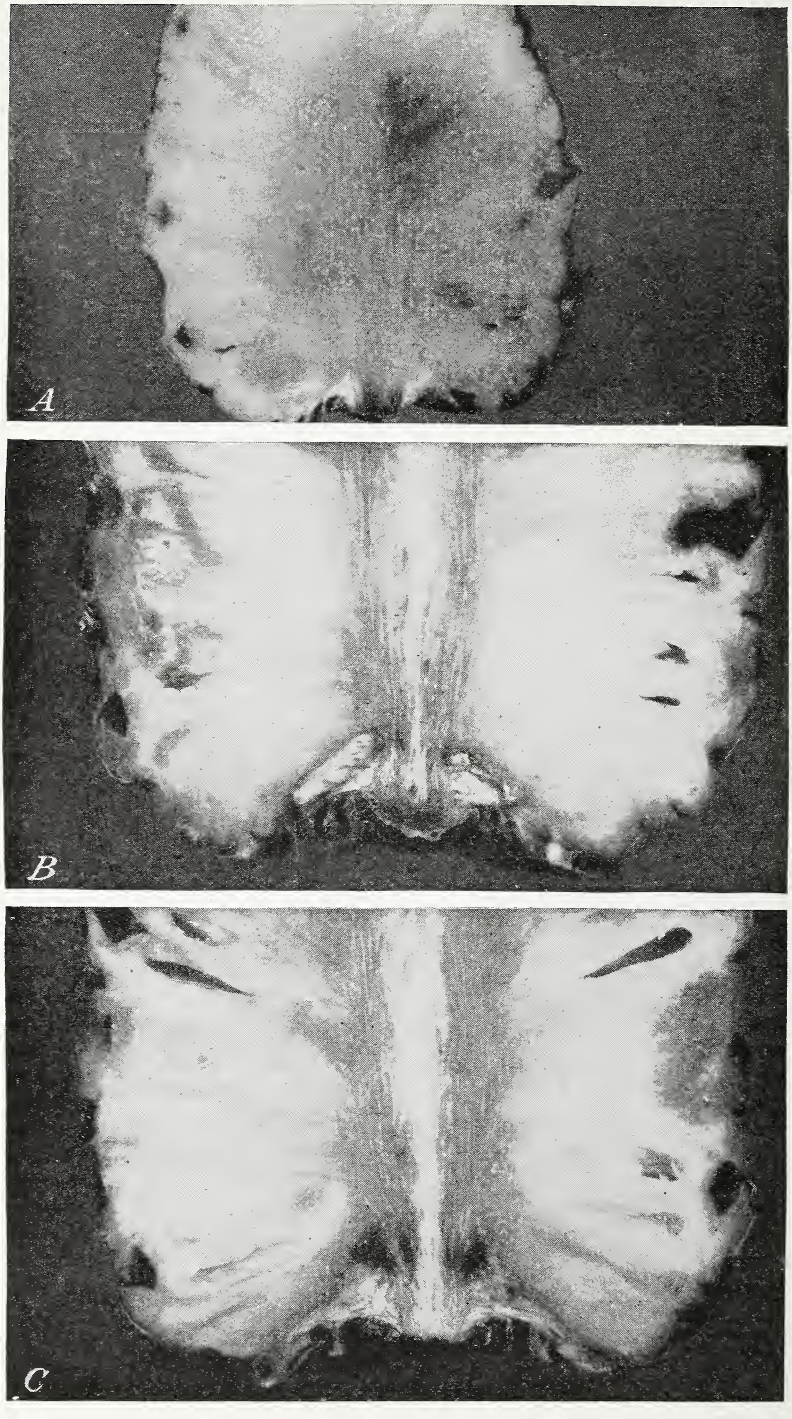

FIGURE 1.—*A*, Black rot of pineapple fruit from infection through the cut stem; *B*, section through base of sound fruit showing normal drying of cut stem; *C*, section through a fruit treated with 1 cc of a solution of 2.5 g of benzoic acid in 100 cc of 30 percent alcohol, showing uninjured stem tissues. Note, in both *B* and *C*, water-soaked packing bruises on sides of fruits.

from infections on the side of the fruit. A few are decayed at the top by infection through the crown leaves.

Since the usual point of entry of the fungus is at the surface of the freshly cut stem, any means of laying down a barrier over this highly susceptible area should prevent much of the decay. For this purpose a number of materials, either as dust or in solution, were tried with varying success. The most uniformly successful material was benzoic acid, which had been found by Dickson, Angell, and Simmonds[2] to control this decay under Australian conditions. The present paper gives the results of experiments to determine the conditions for the most successful application of benzoic acid for the control of black rot in Red Spanish pineapples grown in Puerto Rico and shipped to New York City.

METHODS

Artificially inoculated fruit was used in all tests because regularity of natural inoculation could not be obtained. Uniformly successful inoculations were made by squeezing a drop or two of juice from completely decayed tissue onto the freshly cut stalk at the base of the fruit. For experiments with benzoic acid, this material, dissolved in ethyl alcohol of various dilutions, was applied to the cut stalk of the fruit with a small paint brush either immediately after inoculation or after various intervals. When other materials in dust, paste, or liquid form were tried, they were applied to the stem so that the freshly cut surface was covered. After being treated, the fruits in the holding tests were kept at room temperature (80° to 90° F.) and were examined several times during an 8-day period. Fruits for the shipping tests were usually harvested, inoculated, treated, and packed the day before the boat sailed and were carried under ventilation in the ship's hold. On arrival in New York City they were trucked to the laboratory where they were held at room temperature (70° to 80°). Decay records were made on arrival and at suitable intervals during the time that the fruit would normally take in passing through the marketing channels to reach the consumer.

EXPERIMENTS WITH MATERIALS OTHER THAN BENZOIC ACID

Preliminary tests, as shown in table 1, were made with pineapples treated with a number of disinfectants. Although it was known that some of these were unsuitable for use on fruit (mercuric chloride in particular being highly poisonous), it was desired to try them to obtain a standard of comparison for other materials, which might prove to be effective against the fungus as well as nonobjectionable from the standpoint of use on a food product. Of these materials a proprietary compound in dust form called Trioxotitanium gave the best results, although great variation in control was obtained and in no case did the chemical afford more than about 90-percent control. In some lots it caused slight discoloration of the flesh at the base of the fruit. Trioxotitanium had been found partially effective for black rot control in tests made the previous year.

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[2] DICKSON, B. T., ANGELL, H. R., and SIMMONDS, J. H. THE CONTROL OF SOFT ROT (WATER BLISTER) OF PINEAPPLES CAUSED BY THIELAVIOPSIS PARADOXA. Aust. Council Sci. and Indus. Research Jour. 4: 152–161, illus. 1931.

TABLE 1.—*Control of black rot by treatment of inoculated stems of mature green pineapples with various materials, 1936*

[Fruits used were of the Red Spanish variety grown in Puerto Rico]

Date of treatment	Fruits	Materials applied to cut stem	Time between inoculation and treatment	Decay at stem	Injury from treatment
	Number		*Hours*	*Percent*	
Mar. 11	78	Untreated (check)		97.4	
	31	Trioxotitanium dust	½	93.5	Slight.
	78	do	1½	52.6	Do.
	30	Mercuric chloride, saturated solution in water	½	100.0	
	48	Nickel nitrate, 5-percent solution in water	1¼	20.8	Severe.
	48	Copper oxide 2 parts, chromated zinc chloride 2 parts, slaked lime 6 parts made into paste with water.	1¼	100.0	
Mar. 18	48	Untreated (check)		87.5	
	22	Trioxotitanium dust	(1)	72.7	Slight.
	42	do	1	11.9	None.
	54	Trioxotitanium made into paste with shellac	1	9.3	Slight.
	18	Calcium hypochlorite, 10-percent solution in water.	1	44.4	None.
	42	Terchlorum [2]	1	7.1	Severe.
	18	Calcium hypochlorite made into a paste with shellac.	1	94.4	None. Severe.
	48	Sodium hypochlorite, 5 percent in water	1	25.0	
	64	Colloidal copper sulphate made into paste with water.	1	34.4	Slight.
	24	Colloidal copper sulphate made into paste with shellac.	1	91.7	Do.

[1] Inoculated 3 hours after treatment.

[2] A proprietary compound containing powdered calcium hypochlorite.

Partial control was obtained also with calcium and sodium hypochlorite, but these substances frequently caused injury to the fruit. A 5-percent solution of nickel nitrate in water caused very severe injury, sometimes discoloring as much as one-third of the flesh in a fruit.

Small-scale holding tests in Puerto Rico and in New York City were conducted with various other materials, two of which are mentioned here. Spraying the inoculated cut surface of the stem with a 1-percent solution of maleic acid in amyl acetate gave poor control. Excellent control was obtained with sodium bisulphite applied either as a dust to the stem or as one-half g of powder in the bottom of a small paper bag into which the inoculated fruit was placed. However, when applied in either manner, this material which gives off sulphur dioxide slowly caused severe bleaching of the fruit.

HOLDING EXPERIMENTS WITH BENZOIC ACID

CONTROL OBTAINED WITH VARIOUS CONCENTRATIONS

During March, April, and May 1936 eight experiments were conducted to determine the efficacy of various concentrations of benzoic acid and alcohol. The solutions used were made by dissolving 1 to 20 g of benzoic acid in 100 cc of alcohol varying in strength from 25 to 95 percent. In one case where 10 g of benzoic acid were used in 100 cc of 25-percent alcohol, the solution was heated in order to completely dissolve the acid crystals. Applications were made either 1 or 1¼ hours after inoculation.

The data in table 2, giving the percentage of decay at the end of 8 days, show that the solutions were effective over a wide range of concentrations, both of benzoic acid and of alcohol. Solutions containing 2½ g of benzoic acid in 100 cc of 30-percent alcohol were usually as effective in preventing decay as 20 g of the acid in 100 cc of 95-percent alcohol. With the quantity of benzoic acid reduced to 1 g in 100 cc of 30-percent alcohol the efficacy was greatly diminished. However, with this quantity of acid in 100 cc of 95-percent alcohol the control was good. The efficacy of the solution was not lessened when, with 10 g of benzoic acid in 100 cc of solvent, the alcohol in the solution was reduced from 95 to 25 percent.

TABLE 2.—*Control of black rot of Red Spanish pineapples by applying various concentrations of benzoic acid in alcohol to inoculated stems, 1936*

Date of treatment	Fruits	Maturity of fruits	Benzoic acid used in 100 cc of solvent	Alcohol in aqueous solution	Time between inoculation and treatment	Decay at stem
	Number		*Grams*	*Percent*	*Hours*	*Percent*
Mar. 11	30	Mature green	0	0	----------	100
	48	do	10	50	1¼	2
	48	do	10	95	1¼	2
	48	do	13.3	66	1¼	0
Mar. 16	30	do	0	0	----------	80
	30	do	10	95	[1] 1	0
	30	do	10	95	[2] 1	0
	30	do	10	95	[3] 1	0
	30	do	10	95	[4] 1	0
Apr. 1	24	do	0	0	----------	96
	24	do	6.7	66	1	8
	24	do	13.3	66	1	4
Apr. 8	36	do	0	0	----------	100
	36	do	10	95	1	0
	42	do	13.3	66	1	0
	36	Turning	13.3	66	1	6
Apr. 15	20	Mature green	0	0	----------	80
	20	do	10	65	1	0
	20	do	10	95	1	0
	20	do	20	95	1	0
Apr. 24	30	do	0	0	----------	100
	30	do	0	25	1	27
	24	do	0	50	1	8
	24	do	0	75	1	8
	24	do	0	95	1	12
	30	do	1	95	1	3
	36	do	2.5	30	1	0
	60	do	(5)	30	1	5
	36	do	5	70	1	3
	36	do	[6] 10	25	1	0
	36	do	10	50	1	0
	30	do	10	60	1	0
	30	do	10	60	1	0
May 4	15	do	0	0	----------	100
	15	do	1	30	1	47
	15	do	2.5	30	1	0
	15	Turning	0	0	----------	100
	15	do	1	30	1	73
	15	do	2.5	30	1	0
May 10	17	Mature green	0	0	----------	100
	50	do	2.5	30	1	0
	15	Turning	0	0	----------	100
	50	do	2.5	30	1	2
May 19	24	Mature green	0	0	----------	100
	48	do	1	30	1	38
	48	do	2.5	30	1	0
	48	do	(5)	30	1	2
	48	do	5	95	1	0

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[1] 2 cc of solution applied to each stem: caused some injury.

[2] 1½ cc of solution applied to each stem: caused no commercial injury.

[3] 1 cc of solution applied to each stem: caused no commercial injury.

[4] ½ cc of solution applied to each stem: caused no injury.

[5] More than enough benzoic acid to make a saturated solution was added: about 2.5 g will dissolve under these conditions.

[6] Benzoic acid dissolved by heating the solution.

Dickson, Angell, and Simmonds[3] report that with pineapples in Australia, a solution of not less than 10 percent of benzoic acid in alcoholic solution was required to control soft rot (black rot).

CHEMICAL INJURY

Throughout the investigation, observations were made on the amount of injury produced in the flesh at the base of the fruit. In untreated pineapples there is a normal drying and bleaching of core tissue extending about one-half inch into the fruit (fig. 1, *B*). Sometimes the core splits at the base, and cavities extending more than an inch into the fruit may be formed. It was early noticed that applications of the benzoic-acid solution sometimes increased the drying and bleaching. Since much of the core tissue is discarded in preparing the fresh fruit for the table, this injury is of little importance; however, occasionally a brownish water-soaked condition would be found to have developed in the core and flesh for a depth of one-half inch beyond the bleached area.

An experiment was started on March 16 (table 2) to determine whether the extent of injury could be correlated with the quantity of solution applied. A solution of 10 g of benzoic acid crystals dissolved in 100 cc of 95-percent alcohol was applied to the cut stems in amounts of ½, 1, 1½, and 2 cc per fruit. Control of black rot was obtained with all of the applications. No injury was apparent when ½ cc was applied. Applications of 1 and 1½ cc caused some additional bleaching and some slight but unimportant browning in the core tissue. Fruits treated with 2 cc of the solution showed injury of commercial importance. Part of this injury was to the tissue around the basal or stem cavity in the fruit where the solution had run down from the cut surface and injured the unbroken skin. In other tests in which weaker concentrations of benzoic acid were used and in which care was taken to apply the solution only to the cut stem, no injury of commercial importance was observed (fig. 1, *C*). Control of the decay was obtained when the cut surface of the stem was completely covered with the solution. For most fruits this means that from 0.1 to 0.2 cc was effective.

EFFECT OF DELAY IN APPLICATION OF SOLUTION

To determine how soon after inoculation the solution of benzoic acid must be applied in order to be effective, five experiments were conducted in which the solution was applied from 30 minutes to 10 hours after the fruit was inoculated. After inoculation and treatment the fruit was held at room temperature for 8 days before final decay records were taken.

The data given in table 3 reveal that in two experiments the treatment lost much of its effectiveness when given at the end of the second hour after inoculation. In the final and most extensive experiment, applications made up to and including the third hour following inoculation were successful, whereas those made at the end of the fourth hour were less effective. Although results were not uniform in this respect, they indicated that maximum effectiveness was to be obtained by treatment within the first 2 hours, and that delays of 5 hours would reduce the effectiveness of the application by 12 percent or more.

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[3] Dickson, B. T., Angell, H. R., and Simmonds, J. H. See footnote 2.

Dickson, Angell, and Simmonds[4] in Australia found that, in order to be effective, benzoic acid solution must be applied not later than 5 hours after cutting.

TABLE 3.—*Effect of delay in treating inoculated stems of Red Spanish pineapples with solutions of benzoic acid in alcohol for control of black rot, 1936*

Date of treatment	Fruits	Maturity of fruits	Benzoic acid used in 100 cc of solvent	Alcohol in aqueous solution	Time between inoculation and treatment	Decay at stem
	Number		*Grams*	*Percent*	*Hours*	*Percent*
Feb. 17	12	Mature green	0	0		100
	12	Turning	0	0		100
	12	Mature green	([1] [2])	70	½	0
	12	Turning	([1] [2])	70	1	0
Feb. 24	18	Mature green	0	0		100
	18	Turning	0	0		100
	18	Mature green	([1] [3])	95	1	6
	18	do	([1] [3])	95	1½	0
	18	do	([1] [3])	95	2	17
Mar. 5	14	do	0	0		71
	15	do	([1] [4])	50	½	0
	15	do	([1] [4])	50	1	0
	15	do	([1] [4])	50	1½	7
	15	do	([1] [4])	50	2	33
	27	Turning	0	0		100
	15	do	([1] [4])	50	½	13
	15	do	([1] [4])	50	1	0
	30	do	([1] [4])	50	1½	23
Apr. 1	24	Mature green	0	0		96
	24	do	13.3	66	½	4
	24	do	13.3	66	1	4
June 12	25	do	0	0		72
	25	do	2.5	30	½	0
	25	do	2.5	30	1	0
	25	do	2.5	30	2	0
	25	do	2.5	30	3	0
	25	do	2.5	30	4	8
	25	do	2.5	30	5	12
	25	do	2.5	30	6	12
	25	do	2.5	30	10	32
	25	Turning	0	0		84
	25	do	2.5	30	½	4
	25	do	2.5	30	1	0
	25	do	2.5	30	2	8
	25	do	2.5	30	3	8
	25	do	2.5	30	4	20
	25	do	2.5	30	5	20
	25	do	2.5	30	6	20
	25	do	2.5	30	10	44

[1] More than enough benzoic acid to make a saturated solution was added.
[2] About 31 g will dissolve under these conditions.
[3] About 45.5 g will dissolve under these conditions.
[4] About 12 g will dissolve under these conditions.

EFFECT OF MATURITY OF FRUIT ON EFFECTIVENESS OF TREATMENT

In some experiments duplicate treatments were given "mature green" and "turning" fruits. Included in the former maturity are those fruits that are well filled out but green in color, showing no trace of yellow. This maturity is sometimes called "shipping green" and makes up the bulk of commercial shipments to New York City. Turning fruits include those showing a first trace of yellow to those one-fourth fully colored. Most of this riper fruit is used at local canneries, but an occasional shipment of it under refrigeration is made to New York City.

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[4] ANONYMOUS. WATER BLISTER OF PINEAPPLES. SOFT ROT CAUSED BY THIELAVIOPSIS PARADOXA. Fruit World Australasia 33: 141, illus. 1932.

Data in tables 2 and 3 show that when similar treatments were given fruits of the two maturities, almost twice as much decay occurred in the turning as in the mature green maturity. Apparently greater concentration of benzoic acid is required for control of the decay in turning than in mature green fruit, for in one experiment in which a solution containing 1 g of acid in 100 cc of 30-percent alcohol was used (table 2), 73 percent of the turning fruit decayed, whereas only 47 percent of the mature green fruit decayed. Treatments with 2½ g of acid in 100 cc of 30-percent alcohol usually afforded complete control with both maturities. The results also show that fruit of the riper maturity must be given the treatment sooner after inoculation if similar control is to be obtained.

SHIPPING EXPERIMENTS

TREATMENTS WITH BENZOIC ACID

Seven different shipping tests by boat from Puerto Rico to New York City were conducted from March to June 1936. Treatments of fruits were varied to include those with various dilutions of alcohol in the solvent and various concentrations of benzoic acid in the solutions. All applications of the fungicide were given within 1¼ hours after inoculation.

Data presented in table 4 show that the treatments with benzoic acid were again markedly successful in decreasing decay. As in the holding tests, a solution of 2.5 g of benzoic acid in 100 cc of 30-percent alcohol was found as effective in controlling the decay as solutions of greater concentrations of the acid. In one test 100 cc of 20-percent alcohol was saturated with benzoic acid (approximately 1.2 g) and the resulting solution gave complete control.

In another shipping test duplicate treatments were given fruits grown on light sandy soil and on heavy clay soil. Black rot was controlled more completely on fruit from the latter. However, the difference was not great and since not all of the control fruit in the latter lot decayed, irregularity of inoculation may have been partly responsible for this difference.

Relatively few of the pineapples that were sound on arrival in New York City decayed during the additional 4-day holding period. The temperature of the fruit during the transit period probably greatly influenced the time of appearance of the decay.

TREATMENTS WITH ALCOHOL

Since in one experiment as low as 1-percent solution of benzoic acid was fairly successful in controlling black rot, the question arose as to the effectiveness of alcohol alone. In two of the shipping tests, treatments with 50- and 95-percent alcohol were included. In one of these the control was complete; in the other, 13 and 7 percent, respectively, of the fruit decayed (table 4). A more extensive experiment with various dilutions of alcohol was conducted as a holding test in Puerto Rico. As shown in table 2, treatments with 25-, 50-, 75-, and 95-percent alcohol resulted in 27-, 8-, 8-, and 12-percent decay, respectively. This indicates that although not so effective as in solution with benzoic acid, alcohol alone gave marked control of the decay.

TABLE 4.—*Control during transit and marketing periods of black rot in inoculated stems of mature green fruit of Red Spanish pineapples by treatment with solutions of benzoic acid in alcohol, 1936*

Date of shipment	Fruits	Benzoic acid used in 100 cc solvent	Alcohol in aqueous solution	Time between inoculation and treatment	Decay at stem	
					After transit period of 4 days	Final, including holding period of 4 days
	Number	*Grams*	*Percent*	*Hours*	*Percent*	*Percent*
Mar. 12	[1] 48	0	0	----------	100	100
	[1] 48	10	50	1¼	6	12. 5
	[1] 48	10	95	1¼	12. 5	14. 5
	[1] 48	13. 3	66	----------	0	8
	[2] 48	0	0	----------	67	93
	[2] 48	10	50	½	3	3
	[2] 48	13. 3	66	----------	0	3
Apr. 2	21	0	0	----------	100	100
	21	6. 6	66	½	0	5
	21	6. 6	66	1	5	24
	21	13. 3	66	½	10	14
	21	13. 3	66	1	10	14
Apr. 9	36	0	0	----------	33	44
	36	10	95	1	0	0
	42	13. 3	66	1	0	0
May 1	24	0	0	----------	100	100
	15	0	50	½	0	13
	15	0	95	½	0	7
	15	2. 5	30	½	0	7
	15	2. 5	30	1	7	7
	15	5	50	½	0	0
	15	5	50	1	0	0
	15	5	70	½	0	0
	15	5	70	1	0	0
	15	([3,4])	30	½	7	7
	15	([3,4])	30	1	7	7
	15	([3,5])	12. 5	½	0	0
	15	([3,5])	12. 5	1	0	0
	15	10	50	½	7	7
	15	10	50	1	0	0
	15	10	60	½	0	0
	15	10	60	1	0	0
	15	10	95	½	0	0
	15	10	95	1	0	7
May 14[6]	24	0	0	----------	[7] 54	92
	24	([3,4])	30	1	[7] 0	0
	24	5	50	1	[7] 0	0
	33	5	75	1	[7] 24	30
	24	5	95	1	[7] 0	0
	36	10	70	1	[7] 8	11
	36	10	95	1	[7] 0	0
May 21	18	0	0	----------	61	94
	18	([3,8])	20	1	0	0
	22	2. 5	95	1	0	0
	19	([3,4])	30	1	0	0
	19	5	65	1	0	0
	19	10	50	1	0	0
	19	10	75	1	0	0
	19	10	95	1	0	0
June 6	26	0	0	----------	92	92
	30	0	50	1	0	0
	36	0	95	1	0	0
	42	2. 5	30	1	0	0
	24	2. 5	30	1	0	0

[1] Pineapples grown in Arecibo district on light sandy soil.
[2] Pineapples grown in Corozal district on heavy red clay soil.
[3] More than enough benzoic acid to make a saturated solution was added.
[4] About 2.5 g will dissolve under these conditions.
[5] About 0.7 g will dissolve under these conditions.
[6] Treatments on this date made in field during heavy rain.
[7] Record made day after arrival.
[8] About 1.2 g will dissolve under these conditions.

RELATION OF BRUISING TO SIDE ROT

Since about one-fifth of the black rot in untreated shipments originates on the side of the fruit, observations at shipping point and on the market were made to determine the mode of entrance of the organism. During market repacking of crates containing decayed fruits it was noted that much of the side rot occurred on fruits lying against the sides and top of the crate. Figure 1, *B* and *C*, shows fruits with uninfected water-soaked bruises caused by too tight packing. Observations made in packing houses in Puerto Rico indicated that such bruises were common and were usually caused by using fruits too large for the pack and forcing them into the crates.

Representative crates from several commercial shipments on the pier in San Juan, Puerto Rico, were weighed, and counts were made of fruits showing packing bruises severe enough to produce distinctly flattened areas or to free enough juice to stain the paper wraps. In table 5 these data are presented for a representative shipment in which the fruit stems had been treated with benzoic acid. The percentage of bruised fruits was greater in the larger sizes where differences of as much as 9 pounds in net weight between crates were found. The bruised fruits in the crates examined were removed and held at room temperature (about 85° F.) for 5 days. At the end of that period 6 of the 10 fruits of the 24 size, 2 of the 5 of the 30 size, all of the 7 of the 36 size, and 2 of the 6 of the 42 size were decayed by black rot centering at the bruises. When the shipment from which these crates were taken reached New York, the receiver reported that about 4 percent of the fruits scattered throughout one-third of the crates were decayed. The percentage decayed at the market was somewhat greater than that bruised at the shipping point, but it must be remembered that only severe bruises were counted.

TABLE 5.—*Relation of net weight of fruit to amount of bruising in packs of pineapples of various sizes*

Size 24		Size 30		Size 36		Size 42	
Net weight	Fruits bruised	Net weight	Fruits bruised	Net weight	Fruits bruised	Net weight	Fruits bruised
	No.		*No.*		*No.*		*No.*
76 pounds	3	71 pounds	0	73 pounds	0	74 pounds	0
73½ pounds	0	72 pounds	0	76 pounds	0	74½ pounds	1
72 pounds	0	74 pounds	0	78½ pounds	2	74 pounds	0
80 pounds	5	70½ pounds	0	77 pounds	0	72 pounds	0
72 pounds	0	79 pounds	2	76 pounds	1	73 pounds	0
77½ pounds	0	72½ pounds	0	73 pounds	0	74 pounds	0
78 pounds	2	76 pounds	0	74 pounds	0	75 pounds	2
71 pounds	0	75½ pounds	3	75½ pounds	2	72½ pounds	0
72 pounds	0	72 pounds	0	72 pounds	0	76 pounds	3
73 pounds	0	71 pounds	0	76 pounds	2		
Total	10		5		7		6

Additional information on proper sizing of pineapples was obtained at the packing houses where the mechanical sizers could be set for any size desired, and the resulting pack was examined. Table 6 presents the size and weight of fruits that were found to give tight packs and yet keep bruising to the minimum. Of course, proper sizing does not preclude the necessity for careful handling of fruit in other harvesting and marketing operations, nor will careful handling guarantee freedom from side rot because insects and other agencies in the field may injure the fruit and so allow the fungus to enter.

Table 6.—*Diameter and weight of Red Spanish pineapples of various standard sizes that will make tight but unbruised packs in standard partition crates, 36 by 10½ by 12 inches*

Size	Diameter range	Average net weight		Size	Diameter range	Average net weight	
		Single fruit	Crate			Single fruit	Crate
		Pounds	*Pounds*			*Pounds*	*Pounds*
48	3 11/16 to 3⅞ inches	1 7/16	69	24	4¾ to 5¼ inches	3⅛	75
42	3⅞ to 4⅛ inches	1 11/16	70⅞	18	5¼ to 5⅝ inches	3 15/16	70⅞
36	4⅛ to 4⅜ inches	2	72	16	5⅝ to 6 inches	4 7/16	71
30	4⅜ to 4¾ inches	2 7/16	73⅛	12	6 to 6¼ inches	6 3/16	74¼

COMMERCIAL CONSIDERATIONS

In the spring of 1937 several shippers in Puerto Rico began to use the benzoic-acid treatment on their entire crop. The treatment of some of the early shipments was supervised by one of the writers who made observations on cost and methods of application. Suggestions based on these observations follow.

Grain alcohol of 95 percent strength, denatured by the addition of 10½ ounces of benzoic acid per gallon, may be purchased from local dealers. The cost of the stock solution is about $3 per gallon. Before using it should be diluted with 3.2 times its volume of water (1 part stock solution to 3.2 parts of water). Some care must be exercised in weighing and measuring these ingredients, but since the solution is effective over a wide range of concentrations, extreme accuracy is not necessary.

After the pineapple is removed from the plant it is carried to the end of the row and there set on its top so that its base is exposed to the sun for 2 to 4 hours. With the cut stem thus exposed, application of the solution is facilitated. A glass jar to hold the solution and a small paint brush for its application are all the equipment necessary. Depending on the speed with which the fruit is harvested and made available for the treatment, a man can treat from 8,000 to 12,000 fruits in an 8-hour day. In one of the typical shipments on which records were kept, 9,350 fruits were treated with 2⅗ pints of solution at a cost of $1.35 for material and labor, or one-half cent per box of average-size fruits.

SUMMARY

Benzoic acid in alcoholic solution was the most effective of several materials tried for the control of black rot of pineapples caused by *Thielaviopsis paradoxa* (DeSeyn.) Hoehn. Fourteen holding experiments in Puerto Rico and seven shipping experiments between Puerto Rico and New York were conducted with Red Spanish pineapples to determine conditions influencing the effectiveness of stem treatments with this solution.

Benzoic acid solutions over a wide range of concentrations both of acid and alcohol were effective in controlling the decay. The control obtained with a solution of 2½ g of benzoic acid in 100 cc of 30-percent alcohol was as good as that obtained with solutions of greater concentrations.

Solutions containing 25, 50, 75, and 95 percent of alcohol in water without benzoic acid gave partial control of black rot.

Effectiveness of the treatment decreased with the length of time between inoculation and application of solution. In some experiments applications made at the end of 2 hours were not so effective as those made within the first hour after inoculation.

Treatments with solutions of various strength given at different times after inoculation were not so effective with fruits of turning maturity as with those of mature green maturity, the grade usually shipped commercially.

Observations during packing at shipping point and during repacking on the market indicate that much of the rot on the side of the fruits starts at packing bruises. The proper diameter and weight of fruits for each packing size were determined and are listed.

A solution made up of 2½ g of benzoic acid in 100 cc (about 3⅓ ounces per gallon) of 30-percent alcohol when applied with a small brush only to the cut surface of the stem controlled the decay and caused no injury to the fruit. The cost of labor and material for the treatment is approximately one-half cent per box of fruit.

U. S. GOVERNMENT PRINTING OFFICE: 1939

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